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(54) **COBALT ON ALUMINA CATALYSTS**

KATALYSATOREN AUS COBALT AUF ALUMINIUMOXID

CATALYSEURS AU COBALT SUR OXYDE D'ALUMINIUM

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**Description****Field of the Invention**

**[0001]** The present invention relates to cobalt on alumina catalysts and to a process for making the same.

**Background of the Invention**

**[0002]** In catalysts, cobalt is normally fixed on a carrier such as silica, aluminium silicate, alumina.

**[0003]** In these catalysts, the useful cobalt atoms are those which are exposed at the surface of the cobalt particles. The cobalt atoms which are not exposed (i.e. not at the surface) will not participate in catalytic reaction.

**[0004]** Cobalt is an expensive metal and, in order to optimize its use as a catalyst, it is essential to increase as much as possible the (number of exposed cobalt atoms/ total number of cobalt atoms) ratio of the catalyst which, in turn, increases the cobalt surface area per gram of cobalt.

**[0005]** It is known from EP-A-13,275 to produce a supported coprecipitated cobalt-silica catalyst wherein a reaction mixture of cobalt ions, silicate ions and solid porous carrier particles is prepared and allowed to form a coprecipitate of cobalt and silicate ions onto the solid porous support particles. The obtained cobalt-silica catalyst has a BET total surface area ranging from 150 to 350 m<sup>2</sup>/g and a cobalt surface area ranging from 5 to 20 m<sup>2</sup>/g of cobalt.

**[0006]** It is also known from US-A-4,591,579 to provide a process for the preparation of a transition metal-silicate catalyst in which an insoluble, basic compound of a transition metal (e.g. cobalt, nickel or copper) is precipitated with an alkaline precipitation agent from an aqueous solution of such a metal salt after which this compound is reacted with a silicate solution. In Example 5, it is described such a catalyst wherein the cobalt surface area is 8.9 m<sup>2</sup>/g of catalyst.

**[0007]** It has been proposed in EP - A - 0 029 675 to make catalysts comprising 25 to 70% by weight, based upon the weight of the calcined and reduced catalyst, of a metal such as nickel and/or cobalt by coprecipitating the metal, together with aluminium, in the presence of porous particles such as gamma alumina particles. It is stated that cobalt-containing catalysts preferably contain 25-60% by weight of cobalt and that cobalt-containing catalysts may have cobalt surface areas, as determined by hydrogen chemisorption, in the range 5 to 20 m<sup>2</sup> per gram of catalyst. While a catalyst containing 25% by weight of cobalt and having a cobalt surface area of 20 m<sup>2</sup> per gram of catalyst would have a cobalt surface area of 80 m<sup>2</sup> per gram of cobalt, there is no suggestion that catalysts having such high cobalt surface areas per gram of cobalt can in fact be made by the specified route.

**[0008]** In "Stoichiometries of H<sub>2</sub> and CO Adsorptions on cobalt" — Journal of Catalysis 85, page 63-77 (1984) — are disclosed on page 67, table 1, cobalt catalysts on different carriers. From the total maximum H<sub>2</sub> uptake, it is possible to calculate the cobalt surface area per gram of catalyst and the cobalt surface area per gram of cobalt. It can be seen that, for cobalt on silica catalysts the cobalt surface area per gram of cobalt ranges between 6 and 65 m<sup>2</sup>/g whereas for cobalt on transition alumina catalysts the cobalt surface area per gram of cobalt ranges between 15 and 26 m<sup>2</sup>/g.

**[0009]** Thus, cobalt catalysts with a high cobalt surface area per gram cobalt exist for cobalt on silica catalysts (and also for cobalt on carbon catalysts), but don't exist for cobalt on transition alumina catalysts.

**[0010]** Nevertheless, cobalt upon transition alumina catalysts present some distinct advantages towards other cobalt catalysts.

**[0011]** First of all, a cobalt on transition alumina catalyst is easier to shape by extrusion than a cobalt on silica catalyst and the mechanical strength of the resulting catalyst is higher.

**[0012]** In reactions where water is present (e.g. methanation, Fisher Tropsch), silica can be unstable. Alumina, however is much more stable under such conditions.

**[0013]** There is therefore a need for a cobalt on transition alumina catalyst with a cobalt surface area per gram of cobalt higher than previously obtained.

**[0014]** It is a first goal of the present invention to provide a cobalt on transition alumina catalyst with a cobalt surface area per gram of cobalt higher than previously.

**[0015]** It is a second goal of the present invention to provide a process for manufacturing such catalyst.

**Tests and Definitions****[0016]****i) cobalt surface area**

Approximately 0.5 g of sample is used for the analysis. The weight used to calculate the metallic surface area is that obtained after pretreatment. During this pretreatment the sample is degassed and dried under vacuum at 120°C. The pretreated sample is then reduced. Sample is heated to 425°C at a rate of 3°C/min whilst hydrogen gas is passed through the sample at a flow rate of 250 ml/min. Still with the same hydrogen flow the sample is

maintained at 425°C for 18 hours. Under vacuum the sample is heated up to 450°C over a 10 min time period. The sample is maintained at 450°C under vacuum for 2 hours.

The chemisorption analysis is carried out at 150°C using pure hydrogen gas. An automatic analysis program is used to measure a full isotherm up to 800 mmHg pressure of hydrogen.

The method is to extrapolate the straight-line portion of the chemisorption isotherm between 300 and 800 mmHg to zero pressure to calculate the volume of gas chemisorbed (V).

Metallic surface areas were calculated in all cases using the following equation,

$$\text{Met. S.A.} = \frac{6.023 \times 10^{23} \times V \times \text{SF} \times A}{22414}$$

Where V = uptake of hydrogen in ml/g

SF = Stoichiometry factor (assumed to be 2 for H<sub>2</sub> chemisorption on Co)

A = area occupied by one atom of cobalt (assumed to be 0.0662 nm<sup>2</sup>)

This equation is disclosed by Micromeritics in Operators Manual for ASAP 2000 Chemi System V 1.00, Appendix C, Part No. 200-42808-01, 18 January 1991.

#### ii) Transition alumina

Transition aluminas are defined in "Ullmans Encyklopaedie der technischen Chemie", 4., neubearbeitete und erweiterte Auflage, Band 7 (1974), pp.298-299.

The document divides transition aluminas in several categories:

#### - gamma-group

Included in the gamma-group are, apart from gamma-Al<sub>2</sub>O<sub>3</sub>, all low-temperature forms such as eta-Al<sub>2</sub>O<sub>3</sub> and chi-Al<sub>2</sub>O<sub>3</sub>. They are formed on calcination of aluminium hydroxides at 400-750°C.

The specific surface area of the gamma-group forms of aluminas is in the range of 150-400 m<sup>2</sup>/g.

#### - delta-group

The delta group of aluminas includes all high-temperature forms, e.g. delta-, theta, and chi-Al<sub>2</sub>O<sub>3</sub>. The delta group aluminas are formed on heating gamma-group aluminas at approximately 800°C or higher.

The specific surface area of the delta-group forms of aluminas is in the range of 50-150 m<sup>2</sup>/g.

### General description of the Invention

[0017] It is a first object of the present invention to provide a catalyst, comprising cobalt on a support of transition alumina, having a cobalt content between 3 and 40% by weight, and which, when reduced with hydrogen at 425°C, has a cobalt metal surface area, as measured by hydrogen chemisorption, above 40 m<sup>2</sup> per g of cobalt, preferably above 50 m<sup>2</sup> per g of cobalt, and more preferably above 80 m<sup>2</sup> per g of cobalt.

[0018] Preferably, the transition alumina support is a gamma alumina or, more preferably, a theta alumina.

[0019] Preferably the cobalt catalyst contains 5% to 20% by weight of cobalt, more preferably 10 to 20% by weight.

[0020] It is a second object of the present invention to provide a process for manufacturing a cobalt, on transition alumina support, catalyst containing between 3 and 40% by weight of cobalt, the cobalt surface area being above 30 m<sup>2</sup>/g of cobalt, wherein a slurry of transition alumina in an aqueous solution of cobalt ammine carbonate is heated to a temperature of 60°C to 110°C, in order to allow cobalt hydroxycarbonate to precipitate, the resulting product being then dried and calcined. Optionally, the calcined product may be further reduced.

[0021] Preferably, the transition alumina support is a gamma alumina or a theta alumina, more preferably a theta alumina.

[0022] It is a third object of the present invention to provide a process for manufacturing a cobalt, on transition alumina support, catalyst, containing between 3 and 40% by weight of cobalt, the cobalt surface area being above 30 m<sup>2</sup>/g of cobalt, wherein, transition alumina particles are saturated with an aqueous solution of cobalt ammine carbonate, the excess solution being removed by filtration, the resulting product being heated to a temperature of 60°C to 110°C, in order to allow cobalt hydroxycarbonate to precipitate, the resulting product being then dried and calcined.

[0023] Preferably, the transition alumina support is a gamma alumina or a theta alumina, more preferably a theta alumina.

[0024] Successive impregnation and precipitation steps may be applied to increase the cobalt content, the deposited cobalt hydroxycarbonate being converted into cobalt oxides during a calcination treatment at a temperature of 200 to

600°C.

[0025] The product can then be activated with hydrogen gas at temperatures between 200 and 600°C preferably between 350 and 550°C and then optionally passivated.

#### Specific Description of the Invention

[0026] The present invention will be further described in the following examples.

#### Example 1

[0027]

i) Preparation of the impregnation solution.

Weigh out 1764.0g of a 35% ammonium hydroxide solution (specific gravity 0.88) (obtainable from BDH) and add 73.5 g of demineralised water. Add 312.5g of ammonium carbonate (obtainable from Merck) and start stirring. Heat gently to 35°C to assist dissolving the powder. When fully dissolved, add slowly 350g of basic cobalt carbonate (obtainable from Merck and containing 47-55 wt% Co). Continue stirring for about 2 hours. Filter through Buchner funnel.

ii) Impregnation of  $\theta$ -Al<sub>2</sub>O<sub>3</sub> support

Weigh out 100 g of theta alumina into a beaker and add 0.5 l of the impregnation solution. After 10 minutes put the impregnated extrudates on a Buchner filter to drain excess liquid. Then dry the product for 1 hour at room temperature then 1 hour at 80°C and finally overnight (16h) at 120°C.

Eventually, the dried product is calcined in an air flow at 350°C for 2 hours using a rotary calciner.

#### Example 2

[0028] The dried product obtained in Example 1, after impregnation and before calcination is impregnated once again as disclosed in Example 1, under ii) and dried as disclosed in Example 1 under ii).

[0029] Eventually, the dried product is calcined in an air flow at 350°C for 2 hours using a rotary calciner.

#### Example 3

[0030] The dried product obtained in Example 2, after impregnation and before calcination is impregnated once again as disclosed in Example 1, under ii) and dried as disclosed in Example 1 under ii).

[0031] Eventually, the dried product is calcined in an air flow at 350°C for 2 hours using a rotary calciner.

#### Example 4

[0032] The dried product obtained in Example 3, after impregnation and before calcination is impregnated once again as disclosed in Example 1, under ii) and dried as disclosed in Example 1 under ii). Eventually, the dried product is calcined in an air flow at 350°C for 2 hours using a rotary calciner.

[0033] The products obtained in Examples 1 to 4 were then analysed and the results are as follows:

	Ex. 1	Ex. 2	Ex. 3	Ex. 4
Co (w/w %)	5.9	9.5	11.7	13.2
Surface area (m <sup>2</sup> /g of cobalt)	55.9	91.6	98.3	101.5
Surface area (m <sup>2</sup> /g of catalyst)	3.3	8.7	11.5	13.4

[0034] It can be seen that cobalt on alumina support catalysts with a very high cobalt surface area (per gram of cobalt) can be obtained which enables to have cobalt surface areas (per gram of catalyst) comparable with those obtained in the prior art but with a much lower cobalt content.

[0035] A catalyst according to example 3, after having been activated, was tested for its catalytic activity in the hydrogenation of aromatics, using toluene as a probe.

Reaction conditions:

[0036]

- Pressure : 40 bar H<sub>2</sub>
- LHSV : 3
- Hydrogen flow: 15 ml/min
- Temperature : 200°C
- Catalyst loading : 6 ml (i.e 5 g)

[0037] The conversion of toluene into hydrogenated products was 62% proving that the product of the present invention can be used as an hydrogenation catalyst.

## Claims

1. A catalyst, comprising cobalt on a support of transition alumina, having a cobalt content between 3 and 40% by weight, characterised in that, said catalyst, when reduced with hydrogen, has a cobalt metal surface area, as measured by hydrogen chemisorption, above 40 m<sup>2</sup> per g of cobalt.
2. A catalyst according to claim 1 having a cobalt metal surface area, as measured by hydrogen chemisorption, above 50 m<sup>2</sup> per g of cobalt.
3. A catalyst according to claim 2 having a cobalt metal surface area, as measured by hydrogen chemisorption, above 80 m<sup>2</sup> per g of cobalt.
4. A catalyst according to any one of claims 1 to 3 wherein the support is theta alumina.
5. A catalyst according to any one of claims 1 to 4 having a cobalt content between 5 and 20% by weight.
6. A catalyst according to any one of claims 1 to 5 in the reduced state.
7. A process for manufacturing a catalyst comprising cobalt on a transition alumina support and having a cobalt surface area above 30m<sup>2</sup>/g of cobalt, said process comprising heating a mixture of transition alumina and an aqueous solution of cobalt ammine carbonate to a temperature of 60°C to 110°C in order to allow cobalt hydroxycarbonate to precipitate, drying and calcining the resulting product at a temperature between 200 and 600°C, the amounts of transition alumina and cobalt ammine carbonate employed being such that the calcined product has a cobalt content between 3 and 40% by weight.
8. A process according to claim 7 comprising saturating transition alumina particles with an aqueous solution of cobalt ammine carbonate, and removing the excess of the solution, before heating the resulting product to a temperature of 60°C to 110°C.
9. A process according to claim 7 or claim 8 wherein the transition alumina is a theta alumina.
10. A process according to any one of claims 7 to 9 wherein the transition alumina is in the form of extrudates.
11. A process according to any one of claims 7 to 10 including the step of reducing the calcined product.

## Patentansprüche

1. Katalysator, der Cobalt auf einem Träger von Übergangs-Aluminiumoxid aufweist, der einen Cobaltgehalt zwischen 3 und 40 Gew.-% aufweist, dadurch gekennzeichnet, daß der Katalysator, wenn er mit Wasserstoff reduziert ist, eine Cobalt-Metalloberfläche, und zwar gemessen durch Wasserstoff-Chemisorption, von mehr als 40 m<sup>2</sup>/g Cobalt aufweist.
2. Katalysator nach Anspruch 1 mit einer Cobalt-Metalloberfläche, gemessen durch Wasserstoff-Chemisorption, von

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mehr als 50 m<sup>2</sup>/g Cobalt.

3. Katalysator nach Anspruch 2 mit einer Cobalt-Metalloberfläche, gemessen durch Wasserstoff-Chemisorption, von mehr als 80 m<sup>2</sup>/g Cobalt.
4. Katalysator nach irgendeinem der Ansprüche 1 bis 3, bei dem der Träger theta-Aluminiumoxid ist.
5. Katalysator nach irgendeinem der Ansprüche 1 bis 4 mit einem Cobaltgehalt zwischen 5 und 20 Gew.-%.
6. Katalysator nach irgendeinem der Ansprüche 1 bis 5 im reduzierten Zustand.
7. Verfahren zur Herstellung eines Katalysators, der Cobalt auf einem Übergangsaluminiumoxid-Träger aufweist und eine Cobalt-Oberfläche von mehr als 30 m<sup>2</sup>/g Cobalt aufweist, wobei das Verfahren das Erhitzen einer Mischung von Übergangsaluminiumoxid und einer wäßrigen Lösung von Cobaltammincarbonat auf eine Temperatur von 60°C bis 110°C, um eine Ausfällung von Cobalthydroxycarbonat zu bewirken, das Trocknen und Calcinieren des erhaltenen Produkts bei einer Temperatur zwischen 200 und 600°C umfaßt, wobei die verwendeten Mengen an Übergangsaluminiumoxid und Cobaltammincarbonat so sind, daß das calcinierte Produkt einen Cobaltgehalt zwischen 3 und 40 Gew.-% aufweisen.
8. Verfahren nach Anspruch 7, das die Sättigung von Übergangsaluminiumoxidteilchen mit einer wäßrigen Lösung von Cobaltammincarbonat und das Entfernen des Überschusses der Lösung umfaßt, bevor das erhaltene Produkt auf eine Temperatur von 60°C bis 110°C erhitzt wird.
9. Verfahren nach Anspruch 7 oder Anspruch 8, bei dem das Übergangsaluminiumoxid ein theta-Aluminiumoxid ist.
10. Verfahren nach irgendeinem der Ansprüche 7 bis 9, bei dem das Übergangs-Aluminiumoxid in Form von Extrudaten vorliegt.
11. Verfahren nach irgendeinem der Ansprüche 7 bis 10, das den Schritt des Reduzierens des calcinierten Produkts einschließt.

### Revendications

1. Catalyseur, comprenant du cobalt sur un support constitué d'alumine de transition, ayant une teneur en cobalt comprise dans l'intervalle de 3 à 40 % en poids, ledit catalyseur étant caractérisé en ce que, lorsqu'il est réduit avec de l'hydrogène, il a une surface spécifique du cobalt, mesurée par chimisorption d'hydrogène, supérieure à 40 m<sup>2</sup> par g de cobalt.
2. Catalyseur suivant la revendication 1, ayant une surface spécifique du cobalt métallique, mesurée par chimisorption d'hydrogène, supérieure à 50 m<sup>2</sup> par g de cobalt.
3. Catalyseur suivant la revendication 2, ayant une surface spécifique du cobalt métallique, mesurée par chimisorption d'hydrogène, supérieure à 80 m<sup>2</sup> par g de cobalt.
4. Catalyseur suivant l'une quelconque des revendications 1 à 3, dans lequel le support consiste en thêta-alumine.
5. Catalyseur suivant l'une quelconque des revendications 1 à 4 ayant une teneur en cobalt de 5 à 20 % en poids.
6. Catalyseur suivant l'une quelconque des revendications 1 à 5, à l'état réduit.
7. Procédé pour la production d'un catalyseur comprenant du cobalt sur un support constitué d'alumine de transition et ayant une surface spécifique du cobalt supérieure à 30 m<sup>2</sup>/g de cobalt, ledit procédé comprenant le chauffage d'un mélange d'alumine de transition et d'une solution aqueuse de carbonate de cobalto-ammine à une température comprise dans l'intervalle de 60°C à 110°C afin de permettre la précipitation d'hydroxycarbonate de cobalt, le séchage et la calcination du produit résultant à une température comprise dans l'intervalle de 200 à 600°C, les quantités d'alumine de transition et de carbonate de cobalto-ammine utilisées étant telles que le produit calciné ait une teneur en cobalt comprise dans l'intervalle de 3 à 40% en poids.

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8. Procédé suivant la revendication 7, comprenant la saturation des particules d'alumine de transition avec une solution aqueuse de carbonate de cobalto-ammine, et l'élimination de l'excès de la solution, avant le chauffage du produit résultant à une température comprise dans l'intervalle de 60°C à 110°C.

5 9. Procédé suivant la revendication 7 ou la revendication 8, dans lequel l'alumine de transition est une thêta-alumine.

10. Procédé suivant l'une quelconque des revendications 7 à 9, dans lequel l'alumine de transition est sous forme d'extrudats.

10 11. Procédé suivant l'une quelconque des revendications 7 à 10, comprenant l'étape consistant à réduire le produit calciné.

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